Research & Occasional Paper Series: CSHE.9.10

CSHE | Center for Studies in Higher Education

UNIVERSITY OF CALIFORNIA, BERKELEY

http://cshe.berkeley.edu/

SCIENCE AND THE ENTREPRENEURIAL UNIVERSITY*

July 2010

Richard C. Atkinson
President Emeritus, University of California

Patricia A. Pelfrey
Research Associate, Center for Studies in Higher Education
University of California, Berkeley

ABSTRACT

The current and still-evolving role of the American research university has been shaped by four key developments in the past sixty-five years: the historic decision to establish a comprehensive postwar federal science policy, described in Vannevar Bush's 1945 report, *Science, The Endless Frontier;* the Bayh-Dole Act of 1980; economic analyses from the 1950s onward that have validated the central role of knowledge in economic growth and influenced government and university policy on industry-university research; and various experiments with such research that have led to an increasing integration of research universities and industrial partners in the pursuit of innovation. Can American research universities continue to meet intensifying demands for innovation that advances regional, state, and national economic growth? This paper answers the question with a conditional yes. It describes the trend toward closer relations between universities and industry and how this trend is encouraging new ways of conducting scientific research and new forms of organization within the research university. It concludes with several recommendations for preserving the competitive advantage research universities contribute to American economic leadership: correcting our underinvestment in research in certain disciplines, such as the physical and social sciences; ensuring that federal support for research is sufficient to train graduate students in the numbers needed for national economic competitiveness and to encourage young faculty to pursue research projects with potential for innovative breakthroughs; and to make it easier for foreign-born students to remain in this country once they have earned advanced degrees in American universities.

Introduction

During the second half of the twentieth century, American research universities remade themselves into an important engine of the modern economy. Everyone has heard of the technological miracles wrought by Route 128 in Massachusetts and Silicon Valley in California. Less well known is that high-technology activity, much of it stimulated by research institutions, is estimated to account for sixty-five percent of the difference in economic growth among US metropolitan regions, according to a new book by Jonathan Cole of Columbia University.[1] Cole estimates that the percentage of leading new industries derived from university-based research may run as high as eighty percent.[2] Although research universities represent only a small fraction of the higher-education system—fewer than 200 of over 4000 postsecondary institutions—they are now recognized as essential to American economic leadership.

Yet this is not a moment for self-congratulation. The American economy is beset with difficulties, and as a result universities—especially public universities—are experiencing a painful disequilibrium of their own. Today's climate of economic dislocation is reinforcing the pressures on them to play a more direct and active role in fostering innovation

* Prepared as the basis for Richard C. Atkinson's remarks at the Conference of Presidents of Academies and Scholarly Societies in honor of the fiftieth anniversary of the establishment of the Israel Academy of Sciences and Humanities, March 14-17, 2010, Jerusalem, Israel.

than ever before. Can they do it? The short answer is a conditional yes. First, however, it is important to recognize four broad developments that have shaped the distinctively American role of research universities in the economy:

- The historic decision to establish a comprehensive federal policy on the role of science in the post-World War II era. This policy, in large part the creation of President Franklin Roosevelt's science advisor, Vannevar Bush, was embodied in his 1945 report *Science, The Endless Frontier;*

- The 1980 Bayh-Dole Act, which allowed universities to keep the patent rights to inventions resulting from federally funded research at their institutions;

- Economic analyses that have validated the central role of knowledge in economic growth, influencing both government and university policy on industry-university partnerships;

- Current experiments with new forms of industry-university collaborative research.

The post-World War II paradigm

Vannevar Bush's historic report grew out of the pivotal contributions science and engineering had made to the US war effort. This effort required Bush and his colleagues to organize scientists and engineers to work toward a common goal on a scale never attempted before, and he and President Roosevelt feared the gains would be lost without deliberate policies—a blueprint for supporting science in the postwar world. Bush's intention was to provide industry and the military with a permanent pool of scientific knowledge to ensure economic growth and defense. His strategy was to define the different roles of government, industry, and universities in the scientific enterprise.

The federal government's role would be to be to support basic science generally, not its applications.[3] Industry would be responsible for applied research. Bush reasoned that industry had little incentive to invest heavily in basic research because its results were not proprietary and might be profitably applied by rival firms. American research universities, he decided, should be responsible for producing the pool of fundamental knowledge on which industry could draw. Federal support for university research would be channeled through a system of grants to individual researchers. Each grant would be awarded to projects whose scientific merit had been endorsed through a process of peer review. Congress established the National Science Foundation (NSF) in 1950 to serve as an independent federal agency devoted to supporting basic research and education in all scientific and engineering disciplines.[4]

The most far-reaching premise of Bush's report was never explicitly stated in that document. In arguing for the primacy of basic research, *Science, The Endless Frontier* defined the national research system as residing in its research universities, the locus of most basic scientific research and all graduate and post-graduate education in the United States. Before World War II, the federal government provided virtually no support for research in universities; the very concept of such funding was viewed as a radical idea. In the postwar world, the US government committed itself to becoming the major sponsor of scientific research in universities. It was an extraordinary reversal of direction.

Bush's model—a national scientific enterprise in which basic research, supported with federal funds and conducted by universities, would be implemented by private industry—was a highly simplified version of what actually happens in the discovery and application of new ideas. But his enduring accomplishment was to create a vast system of scientific and technological research organized to produce regular and systematic innovation in the service of economic growth and national security. This is why *Science, The Endless Frontier* remains to this day the single most important document on American science policy ever written.

The Bayh-Dole Act of 1980

Vannevar Bush's report was a landmark of federal policymaking, but by the 1970s the innovative engine it created seemed in need of repair. Strong competition from a reinvigorated Europe and Asia, declining American productivity growth, and rising unemployment made economic competitiveness a major national preoccupation. American universities were producing a rich array of potentially useful research, but innovations were not moving into the private sector as quickly or efficiently as the economy required. The weak link in Bush's model was at the point of transfer from the public to the private sector. The search for better, faster, and more efficient ways of moving university discoveries to market was underway.

The new urgency surrounding technology transfer was in part an unintended consequence of Bush's report. University research partnerships with industry had flourished in the early years of the twentieth century. But these partnerships dimmed in the years after World War II, eclipsed by the sheer volume of federal research funding that poured into research universities in the 1950s and 1960s.

The US government embarked on a series of actions to rebuild American competitiveness during the 1970s, ranging from tax credits for research, to public-private research centers, to an easing of antitrust regulations to encourage research partnerships. For universities, the most far-reaching of these actions was the Patent and Trademark Amendments of 1980, better known as the Bayh-Dole Act. Bayh-Dole was intended to invigorate the technology transfer process from universities and federal laboratories to business and industry. It accomplished this through a fundamental shift in US government patent policy.

Before the 1980 legislation, the federal government owned the rights to any patentable discovery coming out of research supported with federal funds. Yet few research results ever made it to market under this arrangement. Bayh-Dole transferred government's patent rights to universities, leaving it to each institution whether income derived from a patented invention went to individual researchers, the university, or was shared by both. Although the result was to open a new income stream for universities, this was secondary to Bayh-Dole's primary aim: to see that the public investment in basic research served national economic growth.

The influence of Bayh-Dole has been profound, making it far more attractive for universities and industry alike to partner in the commercialization of scientific discoveries. Between 1988 and 2003, US patents awarded to university faculty increased fourfold, from 800 to 3200. Technology transfer offices on research university campuses are now ubiquitous. Most patent income flows from a few hugely successful discoveries, such as the basic technique for DNA recombination or, more recently, the development of pioneering new drugs. Not all technology transfer offices make money and only a few make a great deal. Nonetheless, they are key organizations on university campuses because they offer a ready means for faculty to move research results into the commercial sector.[5]

Thirty years after the passage of Bayh-Dole, some critics complain that universities still do not do enough active technology transfer, either sitting on patents they own or demanding unrealistic value for proprietary rights to university inventions. One proposed solution would allow faculty members to bypass campus technology transfer offices entirely and negotiate their own licensing agreements.[6] From the outset, a broader objection was that Bayh-Dole would be a step down the road to transforming research universities into job shops for private industry, a threat to the integrity of their research and educational missions. This has occurred in some cases when universities have conducted proprietary research funded by industry. The more common experience, however, is that universities and their industrial partners have managed to negotiate successful research arrangements that respect their differences in mission and culture.[7]

Economic analyses

The National Science Foundation was very much involved in the activities generated by the competitiveness crisis of the 1970s. NSF began an analysis of the technology-transfer process and, based on its findings, prepared the legislative draft bill that laid the foundations for the Bayh-Dole Act. It also examined other incentives for investing in research, such as tax credits and industry-university partnerships. These studies led NSF to establish the Industry-University Cooperative Research Program, which supported joint research projects between industry and universities. Industry was responsible for funding its part of the project and NSF funded the university side. The program was novel at the time and created some concerns in the research community. But the quality of the proposals and the excellence of the work quickly established the value of the program and it now has been replicated at other agencies. NSF also established an extramural research program, funding projects to study the relationship between investments in R&D and various types of economic growth.

Economists have long recognized that new inventions and techniques can spur economic growth and productivity. But for many years most members of the profession assumed that new technology was less important than labor and capital in driving economic growth. In the 1950s, Robert Solow of the Massachusetts Institute of Technology challenged this view with a mathematical model demonstrating that only half of economic growth can be traced to labor and capital. The remaining fifty percent, he argued, was due to technical progress.

But relatively little quantitative work on exactly how R&D connects to the economy had been done at the time NSF launched its studies in the 1970s. Edwin Mansfield, an important contributor to these studies, co-authored a landmark 1977 paper on the social and private rates of return on industrial innovations—that is, the benefits that private firms gain from investing in new products and processes compared to the benefits that accrue to society. Mansfield and his colleagues found that the social rate of return was much higher than the rate of return to the firms themselves.[8] The paper provided empirical evidence for Vannevar Bush's argument that private industry has little financial incentive to invest in basic research, which should instead be supported by government as a public good.

Toward the end of his career, Mansfield turned his attention to how basic research in universities stimulates technological change. He wrote an influential 1995 paper assessing how academic research contributed to industrial innovation in sixty-six firms in seven major manufacturing areas, from information processing to pharmaceuticals to petroleum. Mansfield found that academic research was responsible for about eleven percent of the new products and about nine percent of the new processes in the companies he studied.[9] His analysis was a systematic attempt to document the sources, funding, and characteristics of academic research that yields industrial applications. This and many other Mansfield studies helped shape government policy on technology and economic growth.

Later studies have provided further evidence of Mansfield's thesis that publicly supported research is a significant source of industrial applications. A 1997 analysis of American industrial patents found that seventy-three percent of the papers cited were written by researchers at publicly funded institutions (universities, government laboratories, and other public agencies) in the US or foreign countries.[10]

Another development, New Growth Theory, has translated broad intuitive ideas about innovation and economic growth into explicit and elegant mathematical models. Stanford University economist Paul Romer has been a major figure in this domain. His seminal 1990 paper, "Endogenous Technological Change," begins with a question: why has American productivity—output per worker per hour—increased tenfold over the past century, whereas conventional economic theory would lead us to expect that growth would peak at some point and then level off or decline?

Romer's answer: technological change. A century ago, he writes, the only way to elicit visual pleasure from iron oxide was to use it as a pigment. Today it is applied to plastic tape to make videocassette recordings. Incremental improvements like these lie "at the heart of economic growth," according to Romer, and in this respect his model resembles Solow's. Technical progress occurs at an increasingly rapid rate because successive generations of scientists and engineers learn from the accumulated knowledge of their predecessors.[11]

Further, technological change is driven in large part by market incentives. Even if you are a professor on a federal grant with no interest in applying your discoveries, should commercialization occur it will be because an individual or a private firm wants to make a profit. This is why Romer describes technological change not as some external quantity injected into economic activity but as something endogenous—internal—to the economic system itself. Unlike land, labor, and capital, technological change created by human ingenuity holds out the potential of ever-increasing expansion in the wealth of nations. "The most interesting positive implication of the model," he concludes, "is that an economy with a larger total stock of human capital will experience faster growth."[12]

New Growth Theory and subsequent economic and management analyses have given us a greater degree of sophistication in our ideas about how the economic innovation process works; we now have a more complex understanding of the relationship between discovery and application than the 1945 Bush model affords. Recent scholars have emphasized the central role of entrepreneurship and the individual entrepreneur in this process. A study of the origins of the first US biotechnology companies found that active, hands-on involvement of "star" scientists—

scientists who had made original discoveries in the field and understood how to apply techniques of working with recombinant DNA—was indispensable to the early expansion of the biotechnology industry.[13] In biotechnology and certain other fields, the leap from basic science to innovative product is short and getting shorter.

Carl Schramm and Robert E. Litan of the Kauffman Foundation argue that small, entrepreneurial companies are key to pulling the US out of the current recession.[14] Between 1980 and 2005, firms less than five years old were responsible for almost all of the forty million net new jobs (the jobs left after subtracting positions eliminated by downsizing) created in the US. We should be creating an environment, they write, favorable to entrepreneurship generally, but especially to small, discovery-based companies. These companies have the capacity not only to grow quickly and generate jobs. They also become the means of spreading transformative innovations, such as the automobile or Internet search engines that have a deep influence on national prosperity over the long term.

The economic importance of entrepreneurs, start-ups, and small companies has not been lost on state and local governments, many of which are working directly with universities to advance regional economic growth. A California example is the CONNECT program, initially established at the University of California's San Diego campus and now an independent, nonprofit agency. As its name implies, CONNECT brings together university researchers with entrepreneurs, angel investors, and venture capitalists from around the country. It has helped launch hundreds of successful start-up companies in the San Diego area.[15]

CONNECT and similar efforts reflect the competitive realities of the national and global marketplace and the new demands they are bringing to research universities. One is the demand for more, and more interdisciplinary, research, conducted with industrial partners to help translate basic science into new products, processes, and start-up companies. Another is the expectation that research universities will make explicit efforts to take a longer view about the scientific and technological discoveries that will prove essential to the economy ten or twenty years down the road. A third is that they will educate students who are proficient not only in science and technology but also in entrepreneurship.

Some of these goals can be accomplished using the traditional methods and approaches employed in research universities. But others will require a shift in some longstanding attitudes and assumptions about conducting scientific investigation and working with industry. Research universities, in other words, are being asked to become more entrepreneurial themselves. One of the clearest illustrations of this trend is a California initiative to create the next generation of industry-university research partnerships.[16]

The California Institutes for Science and Innovation

In 2000, California governor Gray Davis announced four new interdisciplinary research institutes on University of California campuses, to be chosen by a competitive process and funded through a three-way partnership among government, industry, and the University. The California Institutes conduct fundamental and applied research across many disciplines to achieve the scientific breakthroughs and new technologies that will drive the California economy and improve its society. Educating future scientific leaders is part of their mandate as well, which means that students participate in all phases of research. Each institute involves two or more UC campuses, with one campus taking the lead:

- The California Institute for Telecommunications and Information Technology (Calit2), with UC San Diego as the lead campus in partnership with UC Irvine;

- The California Institute for Quantitative Biomedical Sciences (QB3), with UC San Francisco as the lead campus in partnership with UC Berkeley and UC Santa Cruz;

- The California NanoSystems Institute (CNSI), with UCLA as the lead campus in partnership with UC Santa Barbara; and

- The Center for Information Technology Research in the Interest of Society (CITRIS), with UC Berkeley as the lead campus in partnership with UC Davis, UC Merced, and UC Santa Cruz.

Each collaborates with a wide variety of researchers, students, and private companies. State government contributed $100 million in capital support for each institute, with the requirement that the institutes raise matching funds on a two-to-one basis to the capital funds. Today, the State of California provides $4.75 million annually in operating funds, the University $5.25 million. The rest of the institutes' support comes from federal grants and industry partnerships.

An inspiration for the California Institutes was the renowned corporate research giant AT&T Bell Laboratories, responsible in its heyday for such key scientific advances as the transistor and fiber optics. The era of the big industrial laboratories—Xerox and RCA as well as Bell Labs—is over. But a key lesson of Bell Labs' phenomenal success was the utility of scale in making rapid progress toward the solution of large scientific or technical questions. Whereas other research enterprises might have a dozen or more scientists focused on a particular problem, Bell Labs could marshal hundreds. What if a series of laboratories were created within the University of California System, staffed by a critical mass of researchers from many disciplines, institutions, and industries, all dedicated to creating the scientific discoveries in major fields required for the economic and social prosperity of California?

In part, the California Institutes are an effort to repair the weak link in the 1945 Bush model—technology transfer. In part, they are one state's answer to the innovative vacuum left by the decline of the great industrial laboratories. But they are also an experiment in creating a new research paradigm. This paradigm goes well beyond technology transfer to a closer integration of universities and industry. Its most important assumption is that innovation will be faster and better in institutions that can successfully draw on the different strengths of academic and industrial science.

An example: the California Institute for Telecommunications and Information Technology (Calit2) focuses on the innovative potential of the continual, exponential growth of the Internet and telecommunication. It provides advanced facilities, expert technical support, and state-of-the-art equipment—an environment intentionally designed to allow researchers to work in new ways on new kinds of projects. Fiber-optic cables link the institute to research centers throughout California and around the world.

Most of the space in Calit2 is open, with few private offices. Media artists, cognitive scientists, computer engineers, biochemists, and medical doctors are not normally found working together. At Calit2, it is an everyday occurrence. Most projects last from three to five years; some of the technologies being explored will take more than a decade to develop, others a year or so. At any particular moment there are some thirty grant-funded projects underway. As soon as one project is completed, another takes its place, as researchers rotate in and out of their academic departments. Calit2's unique organization and world-class facilities enable it to shift focus rapidly in accord with the research goals of faculty and of private industry.

The institute has worked with more than 200 firms, from start-ups to established giants, to provide them with many services they cannot produce themselves in a cost-efficient fashion. Sometimes a company wants to support a specific project or have a device tested. Or it may choose to invest in longer-term research and so funds a chair in that area—and later hires a graduate student mentored by the faculty member who held the chair. Other companies may establish corporate sponsorships that bring together researchers to think about the most fundamental of problems. Seven Hollywood studios have joined the Calit2 CineGrid project, which conducts experiments in its state-of-the-art, optical fiber-linked visualization facilities. Ten years after its founding, Calit2 is a leader in the fields of green technology, information theory, photonics and optical networks, digital biology, and technologies that integrate art, science, and computer sciences.

The California Institutes have received high marks to date for the innovative importance of their research accomplishments. Their progress toward the goal of creating the technological infrastructure for the next economy is harder to assess and perhaps premature. At the moment, their most pressing problem is operating funds. Although they have more than succeeded in attaining a two-to-one match for State funds, the Great Recession has left the State of California on the edge of a fiscal precipice.

Universities and institutional change

The new research paradigm envisioned for the California Institutes required a profound institutional change within the University itself. One of the most striking aspects of Calit2 and the California Institutes generally is the way they are shifting traditional academic boundaries.

The co-location of researchers from university, industry, and public agencies—the institutes work on societal challenges as well as economic ones—generates a dynamic environment for thinking about old problems in new ways. It has also created new kinds of learning and career opportunities for students. The institutes are a magnet for both undergraduate and graduate students interested in combining traditional in-depth knowledge of a single field with broad experience of one or two other fields as well. Business students seeking an education in entrepreneurship and innovation find the institutes a rich source of ideas, advisors, and research mentors.

The cross-disciplinary mandate of the California Institutes has required them to challenge the faculty specialization and physical isolation within a department typical of research universities. Calit2, for example, achieved its leadership in taking Internet technologies to the next level because twenty-four academic departments work across disciplines to tackle complex problems, many of which lead to the movement of intellectual discoveries into the marketplace. The institutes' state-of-the-art facilities do more than enable state-of-the-art research. They create an experimental laboratory of innovation open to a broad cross-section of individuals and institutions, whether public or private, profit or non-profit.

The future of innovation

American research universities are one of the best reasons we have for confidence in our economic future. But they are under threat—and that is why the question of whether they will succeed in contributing more to economic growth must be answered with a conditional rather than an unconditional yes. It goes without saying that they must have more State and federal funding as soon as budgetary realities allow—if not before. They are facing other important challenges as well. To mention a few:

- Even before the Great Recession, funding increases for academic research were skewed toward just a few fields, principally the health and biological sciences and engineering. We have been underinvesting in the physical sciences, the earth, atmospheric, and ocean sciences, and the social sciences. This imbalance has been exacerbated by earmarking. Although the annual total of such appropriations is small compared to other kinds of congressional earmarks, the practice damages the peer-review process that has been a cornerstone of the research university system.

- In recent years, the level of all federal research funding for universities has increased very slowly. Most contracts and grants do not include sufficient support to recruit graduate students in the numbers we need for national economic competitiveness in key industries, or to provide enough postgraduate fellowships. Federal funding constraints have imposed an especially heavy burden on younger faculty members. The overall success rate for proposals submitted to NSF is approximately 30 percent; the success rate for proposals from newly appointed PhDs is closer to 20 percent. The fierce competition for funding may discourage faculty, including younger faculty, from submitting proposals that are out of the mainstream and that could yield major breakthroughs.

- The US government should make it easier for foreign-born students who have earned advanced degrees in American universities to stay in this country after their education is finished. According to research by UC Berkeley's AnnaLee Saxenian and her colleagues, one-quarter of all US engineering and technology firms established between 1995 and 2005 had at least one immigrant founder.[17] A follow-up study revealed that over half of the immigrants who had started engineering and technology companies in the US had received their highest degrees at American universities.[18] The US has a record of integrating foreign-born students into its science and technology system that few other nations can match. We should build on that foundation even as we step up efforts to recruit more American-born students into scientific and technological fields.

State and federal policies have encouraged universities to become more active in the development of human capital, entrepreneurship, and industry-university collaboration. Economic analyses have given this trend a theoretical and empirical framework and made a compelling case for the benefits to society. Above all, it would be hard to overestimate the transformative influence of Vannevar Bush and his sweeping redirection of US science policy. In making research universities the core of the American system of scientific and technological innovation, he set them on the path to their current, and still evolving, role in economic growth. The age of the entrepreneurial university has only begun.

---

[1] Jonathan R. Cole, *The Great American University: Its Rise to Preeminence, Its Indispensable National Role, Why It Must Be Protected* (Public Affairs, New York, 2010), p. 198.

[2] Cole, p. 4.

[3] An exception was applied research in support of US defense.

[4] Richard C. Atkinson and William A. Blanpied, "Research Universities: Core of the US Science and Technology System," *Technology in Society,* Vol. 30 (2008), p. 34 ff. Today NSF supplies about twenty percent of all federally supported basic research in American colleges and universities. Many other federal agencies and departments sponsor scientific research as well, among them the National Institutes of Health, which supports fundamental research in medicine and health.

[5] In 1981, for example, patent income to the University of California System was $1.3 million (1981 dollars), and the principal connection with industry was through faculty consulting. In 2008, the University of California System earned $146,314,433 in licensing revenue, with 1913 active licenses, 224 issued in 2008, and 899 new patent applications. UC research produced fifty-five start-up companies that same year. Source: "Licensing Revenue and Patent Activity, 2008 Fiscal Year," *Chronicle of Higher Education,* February 15, 2010.

[6] Kaufman Foundation, *A Roadmap for an Entrepreneurial Economy 2006.* Cited in David B. Audretsch and Ronnie Phillips, "Entrepreneurship, State Economic Development Policy, and the Entrepreneurial University," Centre for Economic Policy Research, Discussion Paper No. 6242, April 2007. Available at www.cepr.org.

[7] Critics of the Bayh-Dole Act have questioned its catalytic role in technology transfer. For example, David C. Mowery and Bhaven N. Sampat believe the legislation's impact has been overstated, arguing that the post-1980 expansion of university patenting and licensing was part of a wave of growing university activity that began in the 1960s and 1970s (David C. Mowery and Bhaven N. Sampat, "The Bayh-Dole Act of 1980 and University-Industry Technology Transfer," *Journal of Technology Transfer,* 30, 1/2, 115-127, 2005). For a skeptical view of Bayh Dole's influence on university science, see R. R. Nelson, whose "Reflections on 'The Simple Economics of Basic Scientific Research,'" (*Industrial and Corporate Change,* October 18, 2006, pp. 1-15), argues that the emphasis on patent and licensing in the wake of Bayh-Dole has tended to limit the broad dissemination of basic research results, even though, in his view, "as a general rule exclusive licensing is not necessary for technology transfer (p.12)."

[8] Edwin Mansfield, John Rapoport, Anthony Romeo, Samuel Wagner, and George Beardsley, "Social and Private Rates of Return from Industrial Innovations," *The Quarterly Journal of Economics,* Vol. 91, No. 2 (May 1977), pp. 221-240.

[9] Edwin Mansfield, "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing," *The Review of Economics and Statistics,* 77, 1, February 1995), p. 55.

[10] F. Narin, K. Hamilton, and D. Olivastro, "The Increasing Linkage between US Technology and Public Science," *Research Policy,* 26, 1997, pp. 317-330.

[11] Paul Romer, "Endogenous Technological Change," *Journal of Political Economy,* Vol. 98, No.5, Part 2: The Problem of Development: A Conference of the Institute for the Study of Free Enterprise Systems (October 1990), pp. S71-S102.

[12] Romer, p. S99.

[13] Lynne G. Zucker and Michael R. Darby, "Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry," *Proceedings of the National Academy of Sciences,* Vol. 93, November 1996, pp. 12709-12716. Zucker and Darby conclude that a firm's collaboration with star scientists is a strong predictor of its success: ". . . for an average firm, 5 articles coauthored by an academic star and the firm's scientists result in about 5 more products in development, 3.5 more products on the market, and 860 more employees (p. 12709)."

[14] Carl Schramm and Robert E. Litan, "An Entrepreneurial Recovery," *Wilson Quarterly,* Spring 2010, Vol. 34, #2, pp. 44-47.

[15] More information on CONNECT and its activities is available at http://www.connect.org/.

[16] Brenda Foust, "The California Institutes for Science and Innovation (Cal ISIs)," Part One, *The Senate Source,* January 2005. Available at http://www.universityofcalifornia.edu/senate/news/source/january.05.senate.source.pdf.

[17] Vivek Wadhwa, AnnaLee Saxenian, Ben Rissing, and Gary Gereffi, "America's New Immigrant Entrepreneurs," January 4, 2007. Available at http://people.ischool.berkeley.edu/~anno/Papers/Americas_new_immigrant_entrepreneurs_I.pdf.

[18] Vivek Wadhwa, AnnaLee Saxenian, Ben Rissing, and Gary Gereffi, "Education, Entrepreneurship, and Immigration: America's New Immigrant Entrepreneurs, Part II," June 11, 2007. Available at http://people.ischool.berkeley.edu/~anno/Papers/Americas_new_immigrant_entrepreneurs_II.pdf.